

**II. The true Theory of the Tides, extracted from
that admired Treatise of Mr. Isaac Newton,
Intituled, Philosophiæ Naturalis Principia
Mathematica; being a Discourse presented
with that Book to the late King James, by
Mr. Edmund Halley.**

IT may, perhaps, seem strange, that this Paper, being no other than a partile Account of a Book long since published, and whereof a fuller Extract was given in Numb. 187. of these Transactions, should again appear here; but the Desires of several honourable Persons, which could not be withstood, have obliged us to insert it here, for the sake of such, who being less knowing in Mathematical Matters; and therefore, not daring to adventure on the Author himself, are notwithstanding, very curious to be informed of the Causes of Things; particularly of so general and extraordinary Phænomena, as are those of the Tides. Now this Paper having been drawn up for the late King James's Use, (in whose Reign the Book was published) and having given good Satisfaction to those that got Copies of it; it is hoped the Savans of the higher Form will indulge us this liberty we take to gratifie their Inferiours in point of Science; and not be offended, that we here insist more largely upon Mr. Newton's Theory of the Tides, which, how plain and easie soever we find, is very little understood by the common Reader.

The sole Principle upon which this Author proceeds to explain most of the great and surprising Appearances of Nature, is no other than that of *Gravity*, whereby in the Earth all Bodies have a tendency towards its Centre;

as is most evident : and from undoubted Arguments is proved, that there is such a Gravitation towards the Centre of the Sun, Moon, and all the Planets.

From this Principle, as a necessary Consequence, follows the Sphærical Figure of the Earth and Sea, and of all the other Cælestial Bodies : and tho' the tenacity and firmness of the Solid Parts, support the Inequalities of the Land above the Level; yet the Fluids, pressing equally and easily yielding to each other, soon restore the *Æquilibrium*, if disturbed, and maintain the exact Figure of the Globe.

Now this force of Descent of Bodies towards the Center, is not in all places alike, but is still less and less, as the distance of the Center encreases : and in this Book it is demonstrated, that this Force decreases as the Square of the distance increases; that is, the weight of Bodies and the force of their Fall is less, in parts more removed from the Center, in the proportion of the Squares of the Distance. So as for Example, a Ton weight on the Surface of the Earth, if it were raised to the height of 4000 Miles, which I suppose the semidiameter of the Earth, would weigh but $\frac{1}{4}$ of a Ton, or 5 Hundred weight : if to 12000 Miles, or 3 semidiameters from the Surface, that is 4 from the Center, it would weigh but $\frac{1}{16}$ part of the Weight on the Surface, or a Hundred and Quarter: So that it would be as easie for the Strength of a Man at that height to carry a Ton weight, as here on the Surface a 100 $\frac{1}{4}$. And in the same Proportion does the Velocities of the fall of Bodies decrease: For whereas on the Surface of the Earth all things fall 16 Foot in a second, at one semidiameter above this Fall is but 4 Foot; and at 3 semidiameters, or 4 from the Centre, it is but $\frac{1}{4}$ of the Fall at the Surface, or but one Foot in a second: And at greater Distances both Weight and Fall become very
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small, but yet at all given Distances is still some thing, tho' the Effect become insensible. At the distance of the Moon (which I will suppose 60 Semidiameters of the Earth) 3600 Pounds weigh but one Pound, and the fall of Bodies is but $\frac{16}{3600}$ of a Foot in a second, or 16 Foot in a minute; that is, a Body so far off descends in a Minute no more than the same at the Surface of the Earth would do in a Second of Time.

As was said before, the same force decreasing after the same manner is evidently found in the Sun, Moon, and all the Planets; but more especially in the Sun, whose Force is prodigious; becoming sensible even in the immense distance of *Saturn*: This gives room to suspect, that the force of Gravity is in the Celestial Globes proportional to the quantity of Matter in each of them: And the Sun being at least ten Thousand times as big as the Earth, its Gravitation or attracting Force, is found to be at least ten Thousand times as much as that of the Earth, acting on Bodies at the same distances.

This Law of the decrease of Gravity being demonstratively proved, and put past contradiction; the Author with great Sagacity, inquires into the necessary Consequences of this Supposition; whereby he finds the genuine Cause of the several Appearances in the Theory of the Moon and Planets, and discovers the hitherto unknown Laws of the Motion of Comets, and of the Ebbing and Flowing of the Sea. Each of which are Subjects that have hitherto taken up much larger Volumes; but Truth being uniform, and always the same, it is admirable to observe how easily we are enabled to make out very abstruse and difficult Matters, when once true and genuine Principles are obtained: And on the other hand it may be wondred, that, notwithstanding the great facility of truth, and the perplexity and nonconsequences that always attend erroneous Suppositions, these

great Discoveries should have escaped the acute Disquisitions of the best Philosophical Heads of all past Ages, and be reserved to these our Times. But that wonder will soon cease, if it be considered how great Improvements Geometry has received in our Memory, and particularly from the profound Discoveries of our incomparable Author.

The Theory of the Motion of the primary *Planets* is here shewn to be nothing else, but the contemplation of the Curve Lines which Bodies cast with a given Velocity, in a given Direction, and at the same time drawn towards the Sun by its gravitating Power, would describe. Or, which is all one, that the Orbs of the Planets are such Curve Lines as a Shot from a Gun describes in the Air, being cast according to the direction of the Piece, but bent into a crooked Line by the supervening Tendency towards the Earths Centre: And the Planets being supposed to be projected with a given Force, and attracted towards the Sun, after the aforesaid manner, are here proved to describe such Figures; as answer punctually to all that the Industry of this and the last Age has observed in the Planetary Motions. So that it appears, that there is no need of solid Orbs and Intelligences, as the Ancients imagined; nor yet of *Vortices* or Whirlpools of the Celestial Matter, as *Des Cartes* supposes; but the whole Affair is simply and mechanically performed, upon the sole Supposition of a Gravitation towards the Sun; which cannot be denied.

The Motion of *Comets* is here shewn to be compounded of the same Elements, and not to differ from Planets, but in their greater swiftness, whereby overpowering the Gravity that should hold them to the Sun, as it doth the Planets, they flie off again, and distance themselves from the Sun and Earth, so that they soon are out of our sight. And the imperfect Accounts and

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Observations Antiquity has left us, are not sufficient to determine whether the same Comet ever return again. But this Author has shewn how Geometrically to determine the Orb of a Comet from Observations, and to find his distance from the Earth and Sun, which was never before done.

The third thing here done is the Theory of the Moon, all the Inequalities of whose Motion are proved to arise from the same Principles, only here the effect of two Centers operating on, or attracting a projected Body comes to be considered ; for the Moon, tho' principally attracted by the Earth, and moving round it, does, together with the Earth, move round the Sun once a Year, and is according as she is, nearer or farther from the Sun, drawn by him more or less than the Center of the Earth, about which she moves ; whence arise several Irregularities in her Motion, of all which, the Author in this Book, with no less Subtility than Industry, has given a full Account. And tho' by reason of the great Complication of the Problem, he has not yet been able to make it purely Geometrical, 'tis to be hoped, that in some farther Essay he may surmount the difficulty : and having perfected the Theory of the Moon, the long desired discovery of the Longitude (which at Sea is only practicable this way) may at length be brought to light, to the great Honour of your Majesty and Advantage of your Subjects.

All the surprizing Phenomena of the Flux and Reflux of the Sea, are in like manner shewn to proceed from the same Principle ; which I design more largely to insist on, since the Matter of Fact is in this case much better known to your Majesty than in the foregoing.

If the Earth were alone, that is to say, not affected by the Actions of the Sun and Moon, it is not to be doubted, but the Ocean, being equally pressed by the
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force of Gravity towards the Center, would continue in a perfect stagnation, always at the same height, without ever Ebbing or Flowing ; but it being here demonstrated, that the Sun and Moon have a like Principle of Gravitation towards their Centers, and that the Earth is within the Activity of their Attractions, it will plainly follow, that the Equality of the pressure of Gravity towards the Center will thereby be disturbed ; and tho' the smallness of these Forces, in respect of the Gravitation towards the Earths Center, renders them altogether imperceptible by any Experiments we can devise, yet the Ocean being fluid and yielding to the least force, by its rising shews where it is less prest, and where it is more prest by its sinking.

Now if we suppose the force of the Moons attraction to decrease as the Square of the Distance from its Center increases (as in the Earth and other Celestial Bodies) we shall find, that where the Moon is perpendicularly either above or below the Horizon, either in Zenith or Nadir, there the force of Gravity is most of all diminished, and consequently that there the Ocean must necessarily swell by the coming in of the Water from those parts where the Pressure is greatest, *viz.* in those places where the Moon is near the Horizon : but that this may be the better understood, I thought it needful to add the following Figure, where *M* is the Moon, *E* the Earth, *C* its Centre, and *Z* the place where the Moon is in the Zenith, *N* where in the Nadir.



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Now by the Hypothesis it is evident, that the Water in *Z*, being nearer, is more drawn by the Moon, than the Center of the Earth *C*, and that again more than the Water in *N*, wherefore the Water in *Z* has a tendency towards the Moon, contrary to that of Gravity, being equal to the Excess of the Gravitation in *Z*. above that in *C* : And in the other case, the Water in *N*, tending less towards the Moon than the Center *C*, will be less pressed, by as much as is the difference of the Gravitations towards the Moon in *C* and *N*. This rightly understood, it follows plainly, that the Sea, which otherwise would be Spherical, upon the Pressure of the Moon, must form it self into a Spheroidal or Oval Figure, whose longest Diameter is where the Moon is Vertical, and shortest where she is in the Horizon; and that the Moon shifting her Position as she turns round the Earth once a day, this Oval of Water shifts with her, occasioning thereby the two Floods and Ebbs observable in each 25 Hours.

And this may suffice as to the general Cause of the Tides; it remains now to shew how naturally this Motion accounts for all the Particulars that has been observed about them; so that there can be no room left to doubt, but that this is the true cause thereof.

The Spring Tides upon the new and full Moons, and Neap Tides on the Quarters, are occasioned by the attractive Force of the Sun in the New and Full, conspiring with the Attraction of the Moon, and producing a Tide by their united Forces: Whereas in the Quarters, the Sun raises the Water where the Moon depresses it, and the contrary; so as the Tides are made only by the difference of their Attractions. That the force of the Sun is no greater in this case, proceeds from the very small Proportion the Semidiameter of the Earth bears to the vast distance of the Sun.

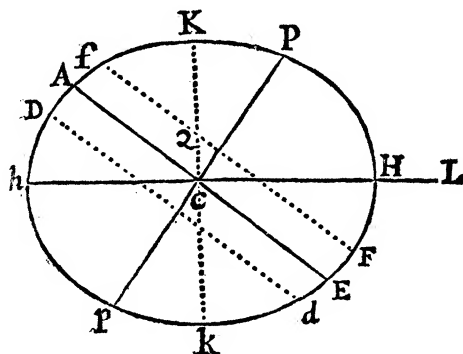
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It is also observed, that *cæteris paribus*, the *Æquinoctial* Spring Tides in *March* and *September*, or near them, are the Highest, and the Neap Tides the Lowest; which proceeds from the greater Agitation of the Waters, when the fluid *Sphæroid* resolves about a great Circle of the Earth, than when it turns about in a lesser Circle; it being plain, that if the Moon were constituted in the Pole and there stood, that the *Sphæroid* would have a fixt Position, and that it would be always high Water under the Poles, and low Water every where under the *Æquinoctial*: and therefore the nearer the Moon approaches the Poles, the less is the agitation of the Ocean, which is of all the greatest, when the Moon is in the *Æquinoctial*, or farthest distant from the Poles. Whence the Sun and Moon, being either conjoyned or opposite in the *Æquinoctial*, produce the greatest Spring Tides; and the subsequent Neap Tides, being produced by the Tropical Moon in the Quarters, are always the least Tides; whereas in *June* and *December*, the Spring Tides are made by the Tropical Sun and Moon, and therefore less vigorous; and the Neap Tides by the *Æquinoctial* Moon, which therefore are the stronger: Hence it happens, that the difference between the Spring and Neap Tides in these Months, is much less considerable than in *March* and *September*. And the reason why the very highest Spring Tides are found to be rather before the Vernal and after the Autumnal Equinox, *viz.* in *February* and *October*, than precisely upon them, is, because the Sun is nearer the Earth in the Winter Months, and so comes to have a greater Effect in producing the Tides.

Hitherto we have considered such Affections of the Tides as are Universal, without relation to particular Cases; what follows from the differing Latitudes of places, will be easily understood by the following Figure.

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Let $A p E P$ be the Earth covered over with very deep Waters, C its Center, P, p , its Poles, $A E$ the $\text{\AE}quinoctial$, $F f$ the parallel of Latitude of a place, $D d$ another Parallel at equal distance on the other side of the $\text{\AE}quinoctial$, $H h$ the two Points where the Moon is vertical, and let $K k$ be the great Circle, wherein the Moon appears Horizontal. It is evident, that a Spheroid described upon $H h$, and $K k$ shall nearly repre-



sent the Figure of the Sea, and $C f$, $C D$, $C F$, $C d$ shall be the hights of the Sea in the places f , D , F , d , in all which it is High-water: and seeing that in twelve Hours time, by the diurnal Rotation of the Earth, the point F is transferred to f , and d to D : the hight of the Sea $C F$ will be that of the High-water when the Moon is present, and $C f$ that of the other High water, when the Moon is under the Earth: which in the case of this Figure is less than the former $C F$. And in the opposite Parallel $D d$ the contrary happens. The Rising of the Water being always alternately greater and less in each place, when it is produced by the Moon declining sensibly from the $\text{\AE}quinoctial$; that being the greatest of the two High-waters in each diurnal Revolution of

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the Moon, wherein the approaches nearest either to the Zenith or Nadir of the place : whence it is that the Moon in the Northern Signs, in this part of the World, makes the greatest Tides when above the Earth, and in Southern Signs, when under the Earth ; the Effect being always the greatest where the Moon is farthest from the Horizon, either above or below it. And this alternate increase and decrease of the Tides has been observed to hold true on the Coast of *England*, at *Bristol* by Capt. *Sturmy*, and at *Plymouth* by Mr. *Colepresse*.

But the Motions hitherto mentioned are somewhat altered by the Libration of the Water, whereby, tho' the Action of the *Luminaries* should cease, the Flux and Reflux of the Sea would for some time continue : This Conservation of the impressed Motion diminishes the differences that otherwise would be between two consequent Tides, and is the reason why the highest Spring Tides are not precisely on the new and full Moons, nor the Neaps on the Quarters ; but generally they are the third Tides after them, and sometimes later.

All these things would regularly come to pass, if the whole Earth were covered with Sea very deep ; but by reason of the shoalness of some places, and the narrowness of the Streights, by which the Tides are in many cases propagated, there arises a great diversity in the Effect, and not to be accounted for, without an exact Knowledge of all the Circumstances of the Places, as of the Position of the Land, and the Breadth and Depth of the Channels by which the Tide flows ; for a very slow and imperceptible Motion of the whole Body of the Water, where it is (for example) 2 Miles deep, will suffice to raise its Surface 10 or 12 Feet in a Tides time ; whereas, if the same quantity of Water were to be conveyed upon a Channel of 40 Fathoms deep, it
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would require a very great Stream to effect it, in so large Inlets as are the Channel of *England* and the *German Ocean*; whence the Tide is found to set strongest in those places where the Sea grows narrowest; the same quantity of Water being to pass through a smaller Passage: This is most evident in the *Streights*, between *Portland* and *Cape de Hague* in *Normandy*, where the Tide runs like a Sluce; and would be yet more between *Dover* and *Calis*, if the Tide coming about the Island from the North did not check it. And this force being once impressed upon the Water, continues to carry it about the level of the ordinary height in the Ocean, particularly where the Water meets a direct Obstacle, as it is at *St. Malo's*; and where it enters into a long Channel, which running far into the Land, grows very straight at its Extremity; as it is in the *Severn-Sea* at *Chepstow* and *Bristol*.

This shoalness of the Sea and the intercurrent Continents are the reason, that in the open Ocean the time of High-water is not at the Moons appulse to the Meridian, but always some Hours after it; as it is observed upon all the West-Coast of *Europe* and *Africa*, from *Ireland* to the *Cape of Good-Hope*: In all which a S. W. Moon makes High-water, and the same is reported to be on the West side of *America*. But it would be endless to account all the particular Solutions, which are easie Corollaries of this *Hypothesis*; as why the *Lakes*, such as the *Caspian Sea*, and *Mediterranean Seas*, such as the *Black Sea*, the *Streights* and *Baltick*, have no sensible Tides: For *Lakes* having no Communication with the Ocean, can neither increase nor diminish their Water, whereby to rise and fall; and Seas that communicate by such narrow Inlets, and are of so immense an Extent, cannot in a few Hours time receive or empty Water enough to raise or sink their Surface any thing sensibly.

Lastly, to demonstrate the excellency of this Doctrine, the Example of the Tides in the Port of *Tunking in China*, which are so extraordinary, and differing from all others we have yet heard of, may suffice. In this Port there is but one Flood and Ebb in 24 Hours; and twice in each Month, *viz.* when the Moon is near the *Æquinoctial* there is no Tide at all, but the Water is stagnant; but with the Moons declination there begins a Tide, which is greatest when she is in the Tropical Signs: only with this difference, that when the Moon is to the Northward of the *Æquinoctial*, it Flows when she is above the Earth, and Ebbs when she is under, so as to make High-water at Moons-setting, and Low-water at Moons-rising: But on the contrary, the Moon being to the Southward, makes High-water at rising and Low-water at setting; it Ebbing all the time she is above the Horizon. As may be seen more at large in the *Philosophical Transaction*, Num. 162.

The Cause of this odd Appearance is proposed by *Mr. Newton*, to be from the concurrence of two Tides; the one propagated in six Hours out of the great *South-Sea* along the Coast of *China*; the other out of the *Indian-Sea*, from between the Islands in twelve Hours, along the Coast of *Malacca* and *Cambodia*. The one of these Tides, being produced in North-Latitude, is, as has been said, greater, when the Moon being to the North of the Equator is above the Earth, and less when she is under the Earth. The other of them, which is propagated from the *Indian-Sea*, being raised in South Latitude, is greater when the Moon declining to the South is above the Earth, and less when she is under the Earth; So that of these Tides alternately greater and lesser, there comes always successively two of the greater and two of the lesser together every day; and the High-water falls always between the times of the arrival

val of the two greater Floods ; and the Low-water between the arrival of the two lesser Floods. And the Moon coming to the *Æquinoctial*, and the alternate Floods becoming equal, the Tide ceases and the Water stagnates : but when she has passed to the other side of the Equator, those Floods which in the former Order were the least, now becoming the greatest, that that before was the time of High-water now becomes the Low-water, and the Converse. So that the whole appearance of these strange Tides, is without any forcing naturally deduced from these Principles, and is a great Argument of the certainty of the whole *Theory*.

III. *An Account of a Child Born alive without a Brain, and the Observables in it on Dissection, by Dr. Charles Preston.*

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IN obedience to your Commands, and judging it will not be unacceptable, I have Collected the best Account (in so far as I can remember) of that extraordinary Birth, mentioned in the fourth Journal of the *Progres de la Medicine*, for the Month of *April*, 1695. of which I had the fortune to be a Witness, and also the opportunity of examining more particularly : But in the first place, I think it not amiss to relate the Story as it is given in by *Monseur Le Duc*, sworn Chirurgion of *Paris*, famous for his Practice in Midwifery ; and I hereafter shall proceed to give a farther History of the thing, with all the Circumstances about it, and show wherein they are in a Mistake.

April